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(54) OPTICAL SCANNING APPARATUS

(71) We, SWEDA INTERNATIONAL INC., a company organized and existing under the laws of the State of New Jersey, United States of America, of 34 Maple Avenue, Pine Brook, New Jersey 07058, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to optical scanning systems and is particularly applicable to optical scanning systems adapted for use in point of sale (POS) applications where articles bearing coded labels or tags can be automatically read at a scanning station. One example of such an optical scanning system is disclosed in U.S. Patent No. 4018504.

The proliferation in the retail grocery industry of articles marked at the source by manufacturers with coded labels conforming to the now widely known Universal Product Code (UPC) has stimulated the development of opto-electronic scanning apparatus capable of efficiently scanning and decoding UPC-type labels. The vast majority of such efforts have relied on laser technology for a practical source of illuminating radiation to scan the labels.

Since the scanning apparatus of this type is intended primarily for installations in supermarkets and other retail grocery outlets serious concern has been raised concerning the safety of consumers and operating personnel who would now be exposed to laser radiation on a frequent basis. In the case of operating personnel, such as a checkstand operator in a food market, the exposure to laser radiation from such a scanner would be continuous over the period of a workshift, repeated on a daily basis for the duration of the workweek.

Clearly, then, the commercial success of such scanning systems is directly dependent on a design which provides efficient, reliable scanning while, at the same time, keeping the scanning beam radiation to acceptably low, safe levels.

It is therefore desirable to provide an optical scanning apparatus which has all of the advantageous features of the scanning apparatus disclosed in U.S. Patent No. 4,018,504 referred to above, while providing even greater safety margins with respect to the amount of laser radiation emitted thereby.

In accordance with the present invention there is provided optical scanning apparatus operable to form, in a scanning plane, a scanning pattern comprising a plurality of intersecting segments in order to scan information on an article, the apparatus comprising:

a rotatable member having a plurality of reflective surfaces disposed around its axis of rotation;

first optical means for directing a plurality of light beams to the rotatable member; and

second optical means for reflecting each light beam, after reflection from the rotatable member, to the scanning plane, the rotation of the member causing each light beam to scan in said plane to form a said segment of the scanning pattern;

the reflective surfaces being disposed at 25 differing angles to the axis of rotation so that each of said segments comprises a plurality of parallel lines.

In the preferred embodiment a laser is used as the light source, and the laser beam is directed through a series of adjusting lenses to a beamsplitter which divides the incoming beam into two beams. These two beams are each reflected off mirrors onto opposite sides of a rotator drum having reflective faces.

The rotator has been constructed so that certain of the reflective faces are sloped towards the rotator axis while other faces are sloped away from the axis relative to a reference edge.

Another set of faces is parallel to the rotator axis. As the drum rotates, the pair of light beams striking the reflective faces of the rotator are reflected back, forming sweep tracings which fall upon the surfaces of an additional pair of mirrors. The latter pair if mirrors is angled to direct the sweep tracings so that they fall within the plane on which the scanning slots are provided. By suitable arrangement of the optical geometry a multiple-X scanning pattern is obtained in the scanning plane.

By virtue of the sloped rotator faces, the leg of each of the multiple X-shaped scan lines is actually comprised of a series of parallel scan lines which are separated by a distance based on the maximum diameter of the human iris in a representative population. In this way the amount of radiation from the light source reaching the eyes of a person in the vicinity of the scanner is substantially reduced, while maintaining scanning integrity.

The scanning apparatus of the preferred embodiment retains all of the various advantageous features recited in the referenced U.S. Patent No. 4018504.

A preferred embodiment of the invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a perspective diagram showing the scanning apparatus of the preferred embodiment;

Figure 2 is a plan view illustrating the nature of the rotator of the apparatus; and

Figure 3 is a plan view of a typical scanning pattern generated by the scanning apparatus of the invention.

Referring now to Figure 1, the output of a light source 10 capable of emitting a highly collimated beam of light 11, such as a laser, is directed through a combination of a convex and a concave lens, or, through a pair of convex lenses forming a beam-forming lens pair 12, which changes the diameter of the light beam by enlarging it while maintaining the collimated characteristic of the beam. A mirror 13 directs the widened collimated light beam 12a through a convex lens 14 onto a beamsplitter 15.

Lens 14 is selected to have a focal length determined by the length of the optical path from lens 14 to the plane in which scanning slots 125-128 (Figure 3) are located, the object being to converge the light ray at the plane in which the slots lie.

Beamsplitter 15 may be a partially transmissive front surface mirror or a beam splitting cube having a square cross sectional area. The light beam 14a falling upon beamsplitter 15 is split into two rays 16 and 17 of substantially equal intensity. Ray 16 is directed to a fixed mirror 18 while ray 17 is directed towards another fixed mirror 19. Mirrors 18 and 19 and located 180°C apart in the preferred embodiment. However, additional mirrors may be provided disposed in other angular arrangements depending on the design of the remaining optical components.

The rotator 200 is an irregular pyramidic frustrum, the lateral sides of which are provided with reflective faces 141, 142, 143, 144, and 145. As best seen in Figure 2, the cross-sectional appearance of rotator 200 may be considered as derived from an imaginary regular pentagon. Each of the sides of the pentagon is divided longitudinally parallel to the axis of rotation of the rotator 200, thus forming a pair of reflective faces associated with each side of the imaginary pentagon or a total of ten reflective faces 141a, 141b, 142a, 142b, 143a, 143b, 144a, 144b, 145a, and 145b.

The edge of each of the reflective faces forms an angle with the side of the imaginary pentagon of 3.1°C in the preferred embodiment for the purposes hereinafter stated. Thus, for example, the angle between reflective faces 142a and 142b would be 173.8° for the 3.1° value given above. However, these angles have been shown greatly exaggerated in Figure 2 of the drawings in order to facilitate understanding of the construction of the rotator 200.

Four of the five pairs 141-145 of reflective faces are sloped towards or away from the longitudinal axis of rotator 200 in the following manner. Consider first the pair of faces 142a, 142b which constitute parallel planes relative to the axis of rotation of the rotator 200. The adjacent pair of faces 143a, 143b are sloped inward from the rotator top surface so that the lower edges 243a, 243b are closer to the axis of rotator 200 than the top edges. Similarly sloped inwardly is the pair 145a, 145b with its lower edges shown as 245a, 245b.

Pair 141a, 141b and pair 144a, 144b are sloped outwardly; that is, the lower edges 246a, 246b and 244a, 244b, respectively, are further away from the axis of rotator 200 than the top edges. In the preferred embodiment, the degree of slope, whether inward or outward, with respect to a plane parallel to the axis of rotator 200 is 0.4156° for the purposes hereinafter described. Obviously, other values for the angular relationships between the faces and the degree of inward and outward sloping could be selected.

Light rays reflected from the surfaces of mirrors 18 and 19 impinge upon the reflective faces of rotator 200 and are reflected back. As the rotator turns (which may be either clockwise, as shown, or counterclockwise), a light ray falling upon one of its faces will be reflected as a moving or sweeping spot, the velocity of which depends on the angular

velocity of the rotator.

Mirrors 23, 24, 31, and 32 are angled with respect to the longitudinal axis of rotator 200 so that as the latter rotates, the locus of light rays reflected from the rotator will trace straight line patterns on a plane surface such as those of the mirrors. These straight light traces are then reflected by virtue of the angular orientation of mirrors, 23, 24, 31, 32 to a plane perpendicular to the axis of rotator 200 hereinafter designated the scanning slot plane which is shown in Figure 3. By appropriately locating and angling mirrors 23, 24, 31, 32, each straight line trace can be made to intersect in the scanning slot plane thereby forming a multiple X-pattern with a ninety degree angle between each leg of the X.

Accordingly, the light trace reflected from mirror 24 will intersect the scanning slot plane to form, for instance, a leg 128c of one X. At an interval of time later, determined by the speed of rotation of rotator 200, the light trace reflected from mirror 23 will intersect the scanning slot plane to form leg 125c of another X.

It is to be understood that, although the drawing for explanatory purposes apparently indicates a plurality of scan lines 125a, 125b, 125c, 128a, 128b and 128c being formed simultaneously by reflection of the traces from the respective mirrors 24, 23, in actual operation each leg of each X is formed in a sequential fashion.

It is to be noted that angled mirrors 24, 23, 31, 32 are equiangularly situated with respect to the axis of rotator 200 along the circumference of an imaginary circle having its center coincident with said axis. As rotator 200 turns and traces the light beam across each of the angled mirrors 23, 24, 31, 32 the beam is reflected therefrom towards the respective scanning slots. Due to the angular orientation of the four mirrors the scanning beam projected towards the scanning slots 125, 126, 127, 128 (Figure 3) will sweep around closed locus.

In the following description, the designation "left" and "right", when referring to mirrors 24, 23, 31, 32, refers to a point of observation at the axis of rotator 200, looking toward the respective mirror.

For example, at a certain instant of time which will be arbitrarily selected as the start of the scanning cycle, light ray 19a is reflected off of face 143a of the rotator 200 and strikes the left edge of mirror 24. As the rototor 200 rotates in a clockwise direction, the ray 122 sweeps across from the left to right edge of mirror 24 which is then reflected onto the scanning plane forming scan line 128C. In a subsequent instant of time, ray 18a is reflected from face 145b onto mirror 23. As rotator 200 turns, ray 121 sweeps across mirror 23 in a left to right direction which ray is reflected onto the scanning plane thereby forming trace 125c. It is to be noted that within each scanning leg 125, 126, 127, and 128 there are three distinct scanning traces formed of a center trace and two parallel traces on each side of the center trace. It is evident from the construction of the rotator 200 that the center trace of each of the legs if formed by the reflection of the light ray from the light source 10 from the reflective face of rotator 200 which is parallel to its axis; namely, faces 142 and 142b. The traces which are furthest away from the axis of rotator 200 are generated by those faces of the rotator which are angled outwardly; namely, faces 141a, 141b and 144a, 144b. On the other hand, the trances which are closest to the axis of rotator 122 are generated by those reflective faces which are sloped inwardly; namely, faces 143a, 143b and 145a, 145b.

As mentioned previously, certain of the reflective faces of rotator 200 are sloped either inwardly or outwardly by an angle of 0.4156° from the vertical. This value was chosen so that the distance between any two scan lines in a given slot is related to the maximum diameter (7 mm. approx) of the human iris and obviously also depends on the distance from the angled mirrors 23, 24, 31, 32 to the scanning slot plane. In this way, the amount of radiation reaching the eye of a person located in the vicinity of the scanning area is markedly reduced thereby ensuring the safe operation of the scanning device.

The following table correlates the generation of the scan lines indicated in Figure 3 with the particular reflective face of rotator 200 producing it. After the generation of the twentieth scan line the cycle repeats periodically. It is to be realized that, by virtue of the geometry of the optical arrangement described, the generation of each scan line is accompanied by one other light ray reflected from the opposite side of rotator 200 and which falls into the blank void between the angled mirrors 23, 24, 31, 32. Since this other ray is not utilized for scanning purposes it may be disregarded for the purposes of the present discussion.

TABLE

Scan line Sequence	Rotator face	Scan line
1	143a	128c
2	145b	125c
3	141a	126a
4	143b	127c
5	144a	128a
6	141b	125a
7	142a	126b
8	144b	127a
9	145a	128c
10	142b	125b
11	143a	126c
12	145b	127c
13	141a	128a
14	143b	125c
15	144a	126a
16	141b	127a
17	142a	128b
18	144b	125a
19	145a	126c
20	142b	127b
21	143a	128c

Consider an article moving across the scanning slots 125, 126, 127, 128 towards the reader. Mirrors 31 and 32 project the scanning beam in a direction away from the reader, sequentially, through slots 126 and 127, respectively, and is able to scan a label appearing on the front or left sides, or front or right sides, respectively. Similarly, the orientation of mirrors 24 and 23 would project the scanning beam, sequentially, through slots 128 and 125, respectively, and is able to scan a label appearing on the rear or right sides, or rear or left sides, respectively.

Obviously, for a label appearing on the bottom side of an article, any one of the four scanning beams is able to properly scan it.

Accordingly, the present scanner has the capability of scanning a label-bearing atticle when the label appears on the bottom, front, rear, or right or left sides. Even articles packaged in irregular configurations such as produce or packages which have become deformed can be similarly read as one or more of the scanning beams sweeps across the label. If a label is not completely scanned by the first sweep by the scanning beam, the missing portions of the label information can be supplied to the decoder during subsequent scanning sweeps, since each article is automatically scanned a large number of times before it can be removed from the scanning slot area.

As discussed previously, coded labels are intended to be scanned by the disclosed device in order to decode the information contained therein. The UPC-type label includes alternate bands of light and dark or otherwise contrasting colors. As the scanning beam sweeps across each one of the four slots which make up the multiple-X scanning pattern, sequentially, the label is illuminated by the beam one or more times.

Light from the scanning beam will be differentially diffused from the surface of the label--depending on whether a light or dark band is illuminated. Since the scanning beam is constantly moving modulated train of diffused light pulses will be produced--the intensity and duration of which depend on the color and width of the bands.

The modulated light pulses reflected from the label return along the same path as the scanning beam which illuminated the article label, thereby permitting the use of a retro-reflective sensing operation. Assuming beam 128c is scanning a label, the modulated pulses will enter the scanning slot 128 associated with scanning beam 128c and strike mirror 24 which reflects the pulses onto face 143a of rotator 200.

A pair of sensors indicated schematically by 27, 30 in Figure 1 is disposed in operative proximity to rotator 200. Convex lenses 28, 29 associated, respectively, with sensors 27, 30 gather the modulated light pulses reflected from the faces of rotator 200 and focus the light onto the sensitive elements forming each sensor. In the example above, only sensor 30 will respond to the modulated light pulses striking face 143a of rotator 200.

Therefore, the sensor will perceive a series of light pulses of varying intensity and duration corresponding to the bars on the coded label. The sensor, being a transducer,

changes the received light energy to a corresponding electrical signal which may then be amplified and fed to appropriate decoding circuitry.

Alternatively, since the light returning from the scanned article follows a truly retro-reflective path, a single sensor may be disposed behind beamsplitter 15 along the path of ray 14a. Mirror 13 may be of the half-silvered, partially-transmissive type enabling the sensor to be placed behind it along an extension of the path or ray 14a.

WHAT WE CLAIM IS:-

1. Optical scanning apparatus operable to form, in a scanning plane, a scanning pattern comprising a plurality of intersecting segments in order to scan information on an article, the apparatus comprising:

a rotatable member having a plurality of reflective surfaces disposed around its axis of rotation;

first optical means for directing a plurality of light beams to the rotatable member; and second optical means for reflecting each light beam, after reflection from the rotatable member, to the scanning plane, the rotation of the member causing each light beam to scan in said plane to form a said segment of the scanning pattern;

the reflective surfaces being disposed at differing angles to the axis of rotation so that each of said segments comprises a plurality of parallel lines.

2. Apparatus as claimed in claim 1, wherein said second means is so arranged that each said light beam successively forms a pair of said segments.

3. Apparatus as claimed in claim 2, wherein said scanning pattern comprises a pair of X's each X being formed by a respective light beam.

4. Apparatus as claimed in any preceding claim, wherein each said segment comprises three parallel lines.

5. Apparatus as claimed in any preceding claim, wherein the reflective surfaces of said rotatable member are equiangularly spaced with respect to said axis.

6. Apparatus as claimed in any preceding claim, wherein the reflective surfaces of said rotatable member are equidistant from said axis.

7. Apparatus as claimed in any preceding claim, wherein said rotatable member has reflective surfaces inclined in opposite directions to the axis of rotation of the rotatable member.

8. Apparatus as claimed in claim 7, wherein the angles of inclination of said oppositely-inclined surfaces are equal.

9. Apparatus as claimed in claim 7 or 8, wherein said rotatable member includes a reflective surface parallel to the axis of rotation.

10. Apparatus as claimed in any preceding claim, wherein said first means includes a beam splitter for dividing a light beam from a source into said plurality of light beams.

11. Apparatus as claimed in claim 10, wherein said first means further includes first and second reflectors each for directing a respective one of said plurality of light beams to said rotatable member.

12. Apparatus as claimed in claim 10 or 11, further including beam forming lens means interposed between said light source and said first means for modifying the diameter of the beam emitted from said source.

13. Apparatus as claimed in any one of claims 10 to 12, further including focussing lens means interposed between said light source and said first means, said focussing lens means having a focal point coincident with said scanning plane.

14. Apparatus as claimed in any preceding claim, including a laser for providing said light beams.

15. Optical scanning apparatus substantially as herein described with reference to the accompanying drawings.

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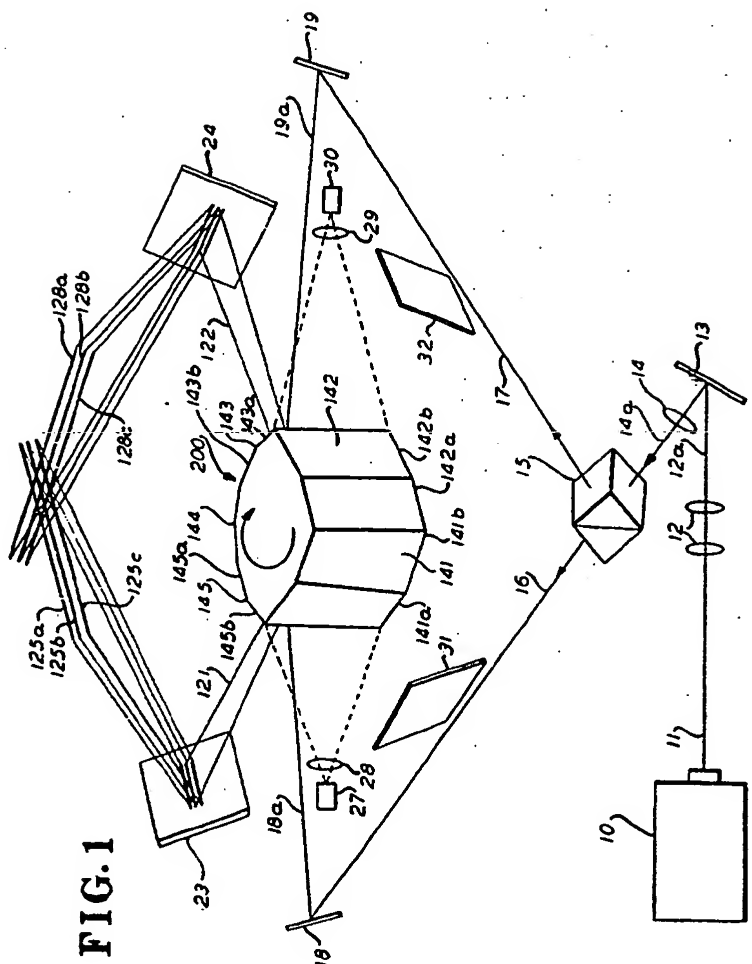
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12
12a
13
14
14a
15
16
17
18
18a
19
19a
23
24
27
28
29
30
31
32
121
122
125a
125b
125c
128a
128b
128c
141
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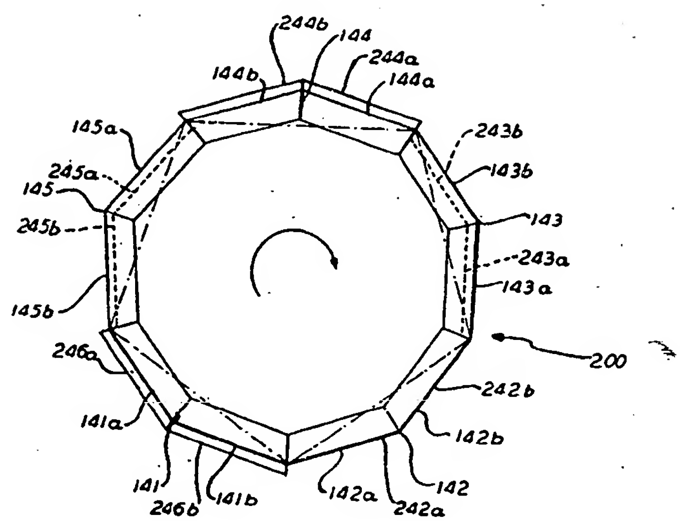
141b
142
142a
142b
143
143a
143b
144
145
145a
145b
200

FIG.1

FIG. 2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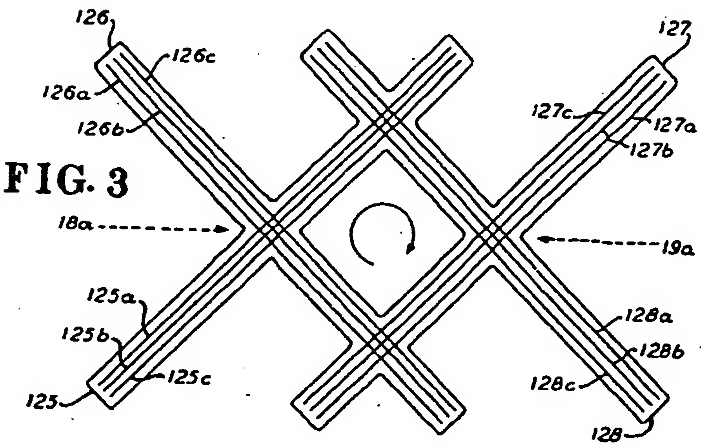
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126c
127
126a
127c
127a
126b
127b
18a
19a
125a
128a
125b
128b
125c
128c
125
128

FIG. 3